SOIL SALINITY IN SALTBUSH COUNTRY OF NORTH-EASTERN SOUTH AUSTRALIA

by R. W. JESSUP*

[Read 10 July 1969]

SUMMARY

A total of 798 soil samples, collected at three different times, were analysed for chlorides. Of these 498 were also analysed for total soluble salts. The samples came from profiles of desert loams in two adjoining paddocks, one supporting saltbush and bluebush shrub-steppe, the other denuded of bush by excessive grazing. The bushes concentrate chlorides in the topsoil under their canopies. This chloride is derived from the soil below and between the bushes and is apparently released from dead leaves that collect under the canopies. There is a progressive increase in chlorides in the topsoil under the bushes and decrease in the surrounding soil during dry periods.

Eroded soils ("scalds") occur in the country denuded of bush. Chloride concentration in the surface of some "scalds" is higher than in equivalent horizons of uneroded soils. Also, less chloride occurs in some soils adjacent to the "scalds" than elsewhere. Apparently chloride has migrated into the "scalds" from these depleted soils.

The distribution of chlorides and of total soluble salts down the profiles shows that there is no significant water movement in the uneroded soils below depths of between 18 in. and 24 in., and in the "scalds" below depths of between 1 in. and 6 in. Measurements of the amount of water held in the soils at field capacity, considered in relation to the rainfall regime, support this conclusion.

INTRODUCTION

In Australia little information is available concerning the effects of the native vegetation on soil properties. The main purpose of the present study was to determine whether bladder saltbush (*Atriplex vesicaria*) and the bluebush (*Kochia astrotricha*), two shrubs that are widely distributed in the southern part of the arid zone, influence the distribution of soluble salts in the soils on which they grow.

The area selected for investigation is in north-eastern South Australia about 30 miles north of Olary, on a plain that was originally entirely covered by shrub-steppe vegetation dominated by saltbush, but with scattered plants of bluebush. However, excessive grazing by stock in the first decade of this century caused complete destruction of the shrub-steppe in part of the area and its replacement by two plant communities, one dominated by grasses and the other by species of *Bassia*. Wind erosion during dry times, when the soil was inadequately protected by these two communities, resulted in an intricate pattern of "scalds" developing on the soil surface. In the "scalds" the topsoil was removed and the clay B horizon exposed.

In order to determine whether saltbush and bluebush affect the distribution of soluble salts, soil samples were collected under the bush canopies, between the bushes, and under both the grass and *Bassia* communities. In addition, samples were taken from the "scalds" so that the salinity of the eroded soils could be compared with that of the uneroded ones.

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THE SALTBUSH COMMUNITY AND THE SOILS SUPPORTING IT

Salinity of the soils supporting a well-preserved stand of saltbush shrub-steppe was investigated on Kalabity Station 0·5 miles south-south-east of the abandoned Telechie homestead. The saltbush and bluebush species present grow to an average height of 15 in. and a canopy diameter of 19 in. They are shallow rooting shrubs, with their roots confined to the upper 24 in. of the soil. The canopies of adjacent bushes are usually separated by distances of 1 to 3 feet. The soil between the bushes is devoid of plants during periods of prolonged drought, but the rainfall (Table 2) during the two years preceding the period when the first samples were collected, had resulted in the growth of *Bassia uniflora*, *B. decurrens*, *Enneapogon avenaceus* and other plants between the bushes (Table 1).

TABLE 1

Botanical composition of the plant communities. The species nomenclature is that of Black (1948). Botanical composition was determined by counting the number of plants of each species in randomly distributed metre quadrats.

	Saltbush community %	Grass community %	*Bassia* community %
Atriplex vesicaria	20·9	0	0
Bassia uniflora	32·9	1·0	6·4
Bassia ventricosa	1·0	0·9	21·3
Enneapogon avenaceus	24·1	88·4	12·1
Bassia decurrens	12·0	2·4	42·5
Kochia astrotricha	2·5	0	0
Malococera tricornis	1·1	0	0
Atriplex limbata	1·8	0	0·7
Sida intricata	1·2	3·1	9·5
Eragrostis dielsii	1·3	3·5	0·4
Stipa nitida	1·0	0·7	0·7
Bassia divaricata	0·3	0	0
Bassia brachyptera	0	0	0·7
Bassia paradoxa	0	0	2·1
Bassia biflora	0	0	0·7
Babbagia acroptera	0	0	2·8

The saltbush community occurs on soils known as desert loams. These soils have texture contrast profiles with shallow, loamy, brown to red A horizons clearly separated from the red, clay B horizons in which there are accumulations of carbonates. The desert loams have an alkaline reaction, are moderately to strongly saline, and have calcium and magnesium as the main exchangeable cations.

Two types of desert loam profiles occur in the area investigated. The most widespread one, referred to as type X, has the following characteristics:

Superficial deposit: A layer of wind-blown sand, 1 in. thick between the bushes and about 4 in. thick under them, overlies the soil profile. The sand is red (2·5 YR 5/6 — 5/8*), has false bedding and is clearly separated from the A horizon of the soil.

A horizon: 6 in. thick. Yellowish red (5 YR 4/6 — 5/6); sandy loam (CS 53%, FS 33%, Si 6%, C 9%); massive. Soft when dry; a little sub-angular gravel; pH 8·6; exchangeable cations—Ca 52%, Mg 28%, Na 6%, K 15%. Sharp boundary to:

* All Munsell colour notations are for soil in the dry state. Consistence terms as defined in the U.S.D.A. Soil Survey Manual (1951) are used. Abbreviations used in the descriptions are CS = coarse sand, FS = fine sand, Si = silt, and C = clay. Exchangeable cations are expressed as percentage of total cations.

B_1 horizon: 10 in. thick. Yellowish red to red (5 YR 4/6 — 2·5 YR 4/6); light clay (CS 33%, FS 21%, Si 7%, C 36%); massive. Slightly hard when dry. Slightly plastic and slightly sticky when wet; a little sub-angular gravel; pH 9·1; exchangeable cations—Ca 54%, Mg 26%, Na 14%, K 6%. Diffuse boundary to:

B_{ca} horizon: Red (2·5 YR 4/6 — 5/8); clay (CS 27%, FS 20%, Si 11%, C 41%); massive. Slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel; many pockets of soft carbonate and much carbonate in the fine earth ($CaCO_3$ 15%); pH 9·8; exchangeable cations —Ca 39%, Mg 32%, Na 26%, K 3%.

Small areas of soil, referred to as type Y, occupy the slightly lower sites on the plain. This soil has the following characteristics:

Superficial deposit: A layer of wind-blown sand, 1 in. thick between the bushes and about 4 in. thick under them, overlies the soil profile. The sand has false bedding and is clearly separated from the A horizon of the soil.

A horizon: 3 in. thick. Light red (2·5 YR 6/6) to red (2·5 YR 5/6); sandy loam (CS 46%, FS 39%, Si 9%, C 7%); massive; soft when dry; often with a little sub-angular gravel. pH 8·9; exchangeable cations—Ca 48%, Mg 26%, Na 9%, K 17%. Sharp boundary to:

"Bleached" top of B horizon: Up to ½ in. thick. Reddish yellow (5 YR 6/6 — 7/8); vesicular; light clay. Slightly hard when dry, slightly plastic and slightly sticky when wet.

B_1 horizon: 7 in. thick. Red (2·5 YR 4/6 — 4/8); light clay (CS 30%, FS 26%, Si 7%, C 37%); prismatic structure, the prisms (1½-3 in. across) breaking fairly easily to sub-angular blocky peds ¼-½ in. in size; slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel. pH 9·1; exchangeable cations—Ca 35%, Mg 36%, Na 26%, K 3%. Diffuse boundary to:

B_{ca} horizon: Red (2·5 YR 4/6 — 5/8); clay (CS 21%, FS 19%, Si 11%, C 47%); massive; slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel; many pockets of soft carbonate and much carbonate in the fine earth ($CaCO_3$ 19%). pH 8·9; exchangeable cations —Ca 35%, Mg 36%, Na 26%, K 3%.

The type Y soil has a shallower A horizon and hence a finer-textured profile than the type X soil, and has higher exchangeable sodium and better structure in the B_1 horizon. The type Y soil also has higher salinity. These differences in profile features are probably due to the fact that the type Y soil occurs on the slightly lower parts of the plain.

VEGETATION AND SOILS IN THE COUNTRY DENUDED OF SALTBUSH

The site selected for the study of soil salinity in country denuded of its saltbush cover, was in Watercourse Paddock on Bimbowrie Station, south of and adjoining the well-preserved stand of saltbush discussed above. The vegetation in Watercourse Paddock consisted of an intricate pattern of two plant communities, one dominated by the grass *Enneapogon avenaceus* and the other by two species of *Bassia* (*B. decurrens* and *B. ventricosa*). The floristic composition of these two communities is shown in Table 1. The grass community occupied 80% of the area and the *Bassia* community 10%. The remaining 10% was devoid of plants.

In the unvegetated areas ("scalds") the A horizon of the soils had been removed by wind erosion and the exposed B horizon was irregularly veneered

TABLE 2

Rainfall (in inches) preceding and between the periods of sampling. The first sampling was carried out during the period 19/5/57 – 12/6/57, the second 28/8/57 – 11/9/57, and the third 23/10/59 – 6/11/59. No rain fell during the sampling periods.

	1954	1955	1956	1957	1958	1959
January	0·24	1·04	1·36	0·00	1·32	0·50
February	0·00	4·50	0·88	0·37	0·33	0·00
March	0·26	2·07	2·81	0·45	1·17	0·48
April	0·52	0·16	0·36	0·14	0·45	0·00
May	0·15	3·27	0·71	0·00	0·42	1·00
June	0·26	1·29	0·92	1·55*	0·00	0·00
July	0·00	0·52	2·20	0·00	0·55	0·37
August	0·00	0·84	0·14	0·26	1·25	1·05
September	0·00	1·33	0·09	0·00	0·23	0·33
October	0·90	0·21	0·39	0·07	2·34	0·66
November	0·00	0·92	0·05	0·00	2·24	0·00
December	2·92	0·00	0·07	1·31	0·70	—
Year	5·51	16·15	9·98	4·15	11·00	—

*1·45 in. fell on June 19-20.

with a lag deposit of gravel. The coarse-textured materials stripped from the "scalds" had accumulated around their margins. Thus in Watercourse Paddock there were areas of uneroded, truncated and of buried types X and Y profiles. The grass community occurred on the uneroded type X soil and on the aeolian deposits.

SOIL SALINITY

Soil samples were collected at three different times, the first in May-June 1957, the second August-September 1957 and the third in October-November 1959. Very little rain had fallen during the 10 months prior to the first sampling period (Table 2). The soils were very dry, in fact tests carried out in the laboratory showed that field moisture was less than that held in the soil at a tension of 15 atmospheres, commonly referred to as the permanent wilting point of plants (Table 3).

TABLE 3

Soil water data derived from laboratory determinations carried out by O. B. Williams, C.S.I.R.O., Division of Animal Physiology, Parramatta, N.S.W.

Soil type	Depth (in.)	Inches of water per stated depth held in the soil: At field capacity	At 15 atmospheres tension	At first sampling time in field
X	0–3	0·60	0·11	0·03
	3–9	0·87	0·27	0·11
	9–18	2·58	1·62	1·04
Y	0–3	1·41	0·12	0·03
	3–9	1·34	1·24	0·49
	9–18	2·01	1·90	0·93
	18–24	1·64	1·34	0·83
	24–30	1·39	1·34	0·89

Field soil moisture was not determined at the time of the second and third samplings. There was one heavy fall of rain (about 1·50 in.) soon after the first sampling (Table 2), but following this and prior to the second sampling there was a period of about 2½ months when very little rain was recorded. The soils were again dry at the time of the third sampling. During the three months prior to this last sampling there was little rain except for one fall of 0·62 in. recorded about 6 weeks prior to sampling time.

Method of sampling

During the first sampling (May-June 1957) the samples were taken at depths of 0-1, 5½-6½, 11½-12½, 17½-18½ and 23½-24½ in. in each profile. For the purpose of discussion, these depths, which include the superficial sand deposit, are referred to as 0-1 in., 6 in., 12 in., 18 in., and 24 in. respectively. Nine profiles of uneroded type X soil, each at least 9 in. away from the nearest bush canopy, were sampled in the shrub-steppe. These sites are referred to as "between bushes" in Tables 4 and 5. Nine profiles of uneroded type X soil were also sampled under the saltbush canopies, and six profiles of uneroded type Y soil under bluebush canopies. In addition, nine profiles each of uneroded type X soil supporting grass, uneroded type Y supporting the *Bassia* community, and "scalded" type Y devoid of vegetation, were sampled in the country denuded of its saltbush cover.

In the second sampling (August-September 1957) samples were collected at depths of 0-1, 5½-6½, 11½-12½, 17½-18½, 23½-24½, 35½-36½, 47½-48½, 59½-60½ and 71½-72½ in. in each profile. All profiles were of uneroded type X soil in the shrub-steppe country. Nine profiles were sampled under both the saltbush and the bluebush canopies, and nine between the bushes.

The third set of samples taken in October-November 1959 were collected at the same depths as the first 1957 sampling. Twelve profiles of uneroded type X soil were sampled in the shrub-steppe in each of three situations, namely under saltbush canopies, under bluebush canopies and between the bushes. Six profiles of uneroded type Y soil were also sampled between the bushes. In the country denuded of its bush cover, six profiles were sampled in the bare "scalds" of both X and Y soils, and six in an area supporting the grass community, adjoining the type X "scald", where 10 in. of sand had accumulated on the same soil type.

Methods used in the laboratory and statistical analyses

The 255 samples collected during the first sampling and the 243 samples from the second sampling were analysed for both chlorides and total soluble salts. The 300 samples from the third sampling were only analysed for chlorides. The chemical analyses were carried out using the methods described by Piper (1942), namely chlorides by electrometric titration and reported as percent sodium chloride present in air dry soil, and total soluble salts by electrical conductivity of a 1 : 5 soil : water suspension.

During the statistical examination of the analytical data it was found that it was necessary to transform the chloride and total soluble salt concentrations to $\log_{10}$ in order to stabilize the variation between the different samples taken at each depth. These $\log_{10}$ figures were always used when determining whether there were significant differences between the various sites.

Results

The analyses show that the type X profile contained less chloride than the type Y profile. During the first sampling (Table 4) the type X profile sampled in the grass community, had a significantly lower chloride concentration at depths of 6 in., 12 in. and 18 in. than the type Y profile sampled in the *Bassia* community.

Similarly, at the time of the third sampling, there was a higher concentration at depths of 0-1 in., 6 and 12 in. in the "scald" of the type X soil than at 6, 12 and 18 in. respectively in the uneroded soil between the bushes. Comparisons must again be made between these depths in the "scalded" and uneroded soils, because the eroded type X profile had lost about 7 in. of topsoil.

The additional chloride in this type X "scald" could have been derived from the soil nearby. During the third sampling, samples were taken from an area adjoining the type X "scald" where sand that had been stripped from the "scald" had accumulated. Beneath the deposit of sand, which was 10 in. in thickness, was uneroded type X soil. There were no significant differences in the chloride concentrations at depths of 12 and 18 in. in the areas where the sand had accumulated compared with depths of 0-1 and 6 in. respectively in the soil between the bushes. However, there was significantly less chloride at a depth of 24 in. where the sand had accumulated than at 12 in. in the soil between the bushes. This may indicate that there had been some loss of chloride from the buried type X soil adjacent to the "scald".

The depth of normal moisture penetration in the soils is indicated by the distribution of chlorides in their profiles. The chloride concentration reached a maximum at 24 in. and was not significantly different at any depth below. This shows that there was no significant water movement in this soil below a depth of between 18 and 24 in. In the "scalds" that were sampled the chloride concentration was constant at and below a depth of 6 in.; this indicates that water normally penetrated to less than 6 in. in these eroded soils.

Total soluble salts were not determined in the samples collected during October-November 1959, but the salt figures for the other two samplings (Tables 5 and 7) showed the same trends as the chloride figures, except that, during the first sampling, the total soluble salt concentration in the type Y "scald" was not significantly higher at 0-1 in. than at 6 in. in the uneroded soil supporting the *Bassia* community.

TABLE 8

Chloride concentrations in samples collected October – November 1959.

(1) Geometric means (Cl as % NaCl) (2) Log_{10} (%NaCl × 10^3). Standard error = mean standard error for all depths at each sampling site.

Depth in inches	Between bushes	Under saltbush	Under bluebush	Between bushes	Bare "scald"	Bare "scald"	Grass
	type X	type X	type X	type Y	type X	type Y	Sand accumulation on type X
0-1	(1) 0·003 (2) 0·477	0·025 1·253	0·011 1·045	0·004 0·602	0·059 1·774	0·033 1·524	0·002 0·338
5½–6½	(1) 0·004 (2) 0·563	0·010 1·053	0·007 0·855	0·061 1·786	0·361 2·557	0·484 2·684	0·003 0·448
11½–12½	(1) 0·032 (2) 1·502	0·059 1·770	0·052 1·714	0·274 2·438	0·390 2·591	0·547 2·738	0·005 0·661
17½–18½	(1) 0·109 (2) 2·038	0·120 2·080	0·110 2·040	0·488 2·688	0·363 2·560	0·484 2·685	0·006 0·789
23½–24½	(1) 0·189 (2) 2·277	0·186 2·269	0·164 2·214	0·509 2·707	0·362 2·559	0·428 2·632	0·010 0·978
Standard error	±0·126	±0·126	±0·126	±0·055	±0·037	±0·130	±0·078

DISCUSSION

The concentration of chlorides and of total soluble salts was significantly higher in the topsoil directly under the saltbush and bluebush canopies than in the soils between the bushes. Furthermore, in the 0-1 in. soil sample, chlorides contributed between $\frac{1}{3}$ and $\frac{1}{2}$ of the total soluble salts under the canopies of the bushes, but only $\frac{1}{8}$ to $\frac{1}{10}$ of those in the soil between the bushes. This shows that there was an absolute increase in the amount of chlorides under the bushes. Thus uneven entry of rainfall into the soils, due to water being shed from the canopies or being lost by direct evaporation from droplets on the leaves, cannot have caused the formation of the pattern of chloride distribution. The observed pattern of chloride distribution must have developed after the bushes became established, because the zone of maximum chloride accumulation (depth 0-1 in.) occurred in the deposit of wind-blown sand that had been "trapped" by the bush canopies.

Apparently the chlorides that were concentrated in the topsoil under the bushes were absorbed from the subsoil under the bush canopies and from the soil between them. At the time of the first sampling the chloride concentration was (1) significantly higher at 0-1 in. under the saltbush canopies, (2) significantly lower under the saltbush canopies at depth of 18 and 24 in., and (3) significantly lower in the soil between the bushes at depths of 12, 18 and 24 in., than in the two later samplings.

During dry times saltbush and bluebush progressively shed their leaves, thereby reducing the amount of water lost through transpiration. The dead leaves accumulate under the canopies. It is proposed that the chlorides that had accumulated in the topsoil under the bush canopies were released from these fallen leaves. Saltbush leaves are known to have a high ash content with the ash consisting principally of sodium chloride (Wood 1925; Beadle, Whalley and Gibson 1957). From its effect on the soil salinity pattern it is inferred that bluebush, which like saltbush belongs to the family Chenopodiaceae, must also concentrate chlorides in its leaves. There was little difference in chloride concentration under the saltbush and bluebush. No comparisons can be made using the data from the first sampling because the soils under the two species were different. In the second sampling, chloride was significantly higher under saltbush than under bluebush at 0.1 in., but the third sampling showed no significant differences. During the second sampling the total soluble salt concentration was not higher under saltbush at 0-1 in.

Accumulation of chlorides would be advantageous to the bushes during times of moisture stress, for the growth of plants with a low chloride tolerance, such as the grasses, would be inhibited and competition for moisture reduced.

Apparently there is a progressive accumulation of chlorides in the topsoil under the bushes and decrease in the surrounding soil during dry periods. Prior to the first sampling time, which was characterized by maximum concentration of chlorides under the bushes and maximum depletion in the surrounding soil, little effective rainfall had fallen for 10 months. However, about 1·50 in. fell some $2\frac{1}{2}$ months prior to the second sampling and 0·62 in. about 6 weeks before the third one (Table 2). There were no significant differences between the second and third samplings in the chloride concentrations in any of the sites either "between bushes", under saltbush canopies or under bluebush canopies.

Saltbush and bluebush are not unique in their effects on the distribution of soil salts. Roberts (1950), and Fireman and Hayward (1952) have shown that several kinds of bushes that grow in semi-arid environments in the United States, concentrate salts in the soil under their canopies.

The analyses show that in the type X soil, the chloride concentration reached a maximum at 24 in. and then remained constant with depth. This indicates that there was no significant water movement in the soil below a depth of between 18 and 24 in. Jackson (1958) concluded that the maximum depth of rainwater penetration into similar soils at Yudnapinna Station, where the climate is similar, was also between 18 and 24 in.

A consideration of the rainfall in relation to the amount of water required to bring the soil to field capacity, 4 in. (see Table 3), also indicates that water would penetrate the type X profile to between 18 and 24 in. At the first sampling time the moisture content of type X soil was less than that held at a tension of 15 atmospheres, commonly referred to as the permanent wilting point of plants (Table 3). The top 18 in. contained just over 1 in. of water, so a fall of about 3 in. of rain would have been required to raise this depth of soil to field capacity. Table 3 also shows that the top 18 in. of the type Y soil holds about 4·75 in. of water at field capacity. At the first sampling time about 3·3 in. of rain would have been required to bring this depth to field capacity.

Single falls of rain as high as 3 in. are rarely received in the study area; during the 6 year period 1954-1959 falls of about 3 in. per *month* were only recorded on 3 occasions (Table 2). Once, in 1955, an exceptionally large amount of rain, 4·5 in., fell during February. Lack of penetration of water below 24 in. would explain why saltbush and bluebush roots do not penetrate below this depth, and is probably the reason for the absence of trees in this country.

ACKNOWLEDGEMENTS

Statistical analyses of the chloride and total soluble salt figures were made by Messrs. K. Cellier and G. A. McIntyre, C.S.I.R.O., Division of Mathematical Statistics, and the former offered many helpful suggestions regarding the interpretation of the data. All of the chemical analyses were carried out in the laboratories of the C.S.I.R.O., Division of Soils, Canberra, under the direction of Mr. H. J. Beatty. A number of people assisted with field samplings at different times, notably Messrs. G. and S. Scholz formerly of Bimbowrie Station, and Mr. O. B. Williams, C.S.I.R.O., Division of Animal Physiology, Parramatta.

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A CONTRIBUTION TO THE MESOPHYTIC FLORA OF SOUTH AUSTRALIA

BY HEINZ AMTSBERG†

Summary

An introductory description of the macroflora of the Springfield Triassic Basin and the analysis of its age are given. The following palaeobotanical divisions are represented: Ginkgophyta, Arthrophyta, Pteridospermophyta, also Gymnospermous seeds and Incerae sedis.

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(Springfield and Leigh Creek)

by HEINZ AMTSBERG†

[Read 10 July 1969]

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An introductory description of the macroflora of the Springfield Triassic Basin and the analysis of its age are given. The following palaeobotanical divisions are represented: Ginkgophyta, Arthrophyta, Pteridospermophyta, also Gymnospermous seeds and Incertae sedis.

INTRODUCTION

In 1957 leaf impressions of Triassic age were found by students of the University of Adelaide under the leadership of Dr. Kleeman, approximately 46 km north of Quorn in the Flinders Ranges of South Australia. These impressions were identified by Ludbrook (1961) as *Dicroidium feistmanteli* (Johnston) and freshwater molluscs *Unio* and *Protovirgus* were described by Ludbrook from the same source. In 1958 and 1959 comprehensive drilling in search of coal was carried out at Springfield by the South Australian Department of Mines, but the project was abandoned as only thin seams of coal were discovered.

In 1965 the writer examined fossil plant specimens from Springfield lodged with the University of Adelaide, which prompted the present investigations.

METHOD

The Springfield Triassic Basin (Lat. 37° 07′ S, Long. 138° 25′ E) is situated some 375 km north of Adelaide in an undulating section of the Flinders Ranges, bordering the Willochra plain.* The roads from Adelaide are bituminized, with the exception of the last 15 km which are bush tracks. Due to some hazardous creek beds in the latter section, the locality should be visited during the dry season, using a four-wheel-drive vehicle.

The specimens, unless specifically stated otherwise, were collected by the writer during the years 1965 to 1969, on the central mesa of the Springfield Basin, Section 48 Hundred of Cudla Mudla. They were picked up from the surface, or dug out from a depth of up to 20 cm. Where a specimen is mentioned with its counterpart, the original rock was split open by the writer on the site.

Descriptions are based on hand lens observations, microscopic investigations have not been carried out.

All described specimens have been listed and deposited with The South Australian Museum, Adelaide. The numbers with the prefix P, shown in brackets in the text, are the Museum registration numbers.

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* For locality map see *Trans. R. Soc. S. Aust.* 84: 140, for geological map see Willochra Geological Survey sheet, Department of Mines, Adelaide.